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Water pollution and the assessment of water quality parameters: a review
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Abstract
The entry of pollutants into the water bodies has deteriorated the quality of freshwater which led to the occurrence of water pollution. The factors of water pollution due to natural processes are cli-mate change and natural disasters. The anthropogenic activities that affect water quality are urban-ization, development of infrastructures, industrial applications, agricultural activities, and sediment runoff. The severity of water pollution is measured using physical, chemical, and biological param-eters. For biological parameters, metagenomics analysis is associated with bioinformatics in detect-ing, identifying, and characterizing the microorganisms present in the environment. The methods carried out from the data analysis through the bioinformatics study are bacterial abundance, rar-efaction curve, core microbiome, clustering analysis and diversity analysis. Turbidity, temperature, electrical conductivity (EC), and total dissolved solids (TDS) are the physical parameters whereas pH, nutrients (ammoniacal nitrogen and phosphorus), dissolved oxygen (DO), and heavy metals are the chemical parameters. A thorough and detailed study needs to be done to correlate the sources of water pollution and the water quality of freshwater. Therefore, proper treatment can be carried out to improve the water quality of the freshwater according to the class in DOE-WQI.

Author Keywords
Biological parameters; Chemical parameters; Physical parameters; Water pollution; Water quality

References

- Kılıç, Z.
  The importance of water and conscious use of water
  (2002) *Int. J. Hydrol*, 4, pp. 239-241.
- Boretti, A., Rosa, L.
  Reassessing the projections of the World Water Development Report
  (2019) *npj Clean Water*, 2.
- Schweitzer, L., Noblet, J.
  (2018) *Chapter 3.6 – Water Contamination and Pollution, Green Chemistry: An Inclusive Approach*, pp. 261-290.
  Elsevier Inc., Amsterdam, The Netherlands
- Chaudhry, F.N., Malik, M.F.
  Factors affecting water pollution: a review
  (2017) *J. Ecosyst. Ecography*, 7, pp. 1-3.
- Song, J.H., Murphy, R.J., Narayan, R., Davies, G.B.H.
  Biodegradable and compostable alternatives to conventional plastics
  (2009) *Phil. Trans. R. Soc. B*, 364, pp. 2127-2139.
- Emetere, M.E., Aimudo, O.
  Pollution from non-biodegradable electrical wastes: risk analysis of lead (Pb) contaminants
  (2020) *IOP Conf. Ser.: Earth Environ. Sci*, 563.
- Huang, Y.F., Ang, S.Y., Lee, K.M., Lee, T.S.
  Quality of Water Resources in Malaysia

(2015) *Research and Practices in Water Quality, InTechOpen*,
T.S. Lee. Ed

- Idris, A.B., Mamun, A.A., Amin, M., Soom, M., Noor, W., Azmin, W.
Review of water quality standards and practices in Malaysia
(2003) *Pollut. Res*, 22, pp. 145-155.

- Akhtar, N., Syakir Ishak, M.I., Bhawani, S.A., Umar, K.
Various natural and anthropogenic factors responsible for water quality degradation: a review
(2021) *Water (Switzerland)*, 13, p. 2660.

- Khatri, N., Tyagi, S.
Influences of natural and anthropogenic factors on surface and groundwater quality in rural and urban areas
(2015) *Front. Life Sci*, 8, pp. 23-39.

- Prathumratana, L., Sthiannopkao, S., Kim, K.W.
The relationship of climatic and hydrological parameters to surface water quality in the lower Mekong River
(2008) *Environ. Int*, 34, pp. 860-866.

- Sholihah, Q., Kuncoro, W., Wahyuni, S., Puni Suwandi, S., Dwi Feditasari, E.
The analysis of the causes of flood disasters and their impacts in the perspective of environmental law
(2020) *IOP Conf. Ser.: Earth Environ. Sci*, 437.

- Gupta, A., Singh, M.R.
(2016) *Water Pollution-Sources, Effects and Control*,
Centre for Biodiversity, Department of Botany, Nagaland University

- Abdel-Shafy, H.I., Mansour, M.S.M.
Solid waste issue: sources, composition, disposal, recycling, and valorization
(2018) *Egypt. J. Pet*, 27, pp. 1275-1290.

- Burri, N.M., Weatherl, R., Moeck, C., Schirmer, M.
A review of threats to groundwater quality in the anthropocene
(2019) *Sci. Total Environ*, 684, pp. 136-154.

- Mateo-Sagasta, J., Zadeh, S.M., Turral, H., Burke, J.
(2017) *Water Pollution From Agriculture: A Global Review*,
Executive Summary, Published by the Food and Agriculture Organization of the United Nations Rome, 2017 and the International Water Management Institute on Behalf of the Water Land and Ecosystems Research Program Colombo

- Holt, M.S.
Sources of chemical contaminants and routes into the freshwater environment
Food Chem. Toxicol, 38 (200), pp. 21-27.

- Jain, M.K., Das, A.
Impact of mine waste leachates on aquatic environment: a review
(2017) *Curr. Pollut. Rep*, 3, pp. 31-37.

- Hassaan, M.A., El Nemr, A.
Pesticides pollution: classifications, human health impact, extraction and treatment techniques
(2020) *Egypt. J. Aquat. Res*, 46, pp. 207-220.

- Kim, K.H., Kabir, E., Jahan, S.A.
Exposure to pesticides and the associated human health effects
(2017) *Sci. Total Environ*, 575, pp. 525-535.

- Camara, M., Jamil, N.R., Bin Abdullah, A.F.
Impact of land uses on water quality in Malaysia: a review
(2019) *Ecol. Processes*, 8 (2019).

- Garba, T.E., Richard, R.L., Thani, N.E.A., Majid, M.A.A., Lawal, M., Yelwa, N.A.
Geological effects on water quality: a review of issues and challenges in Malaysia
(2021) *Sains Malaysiana*, 50, pp. 1857-1870.

- Kurunc, A., Ersahin, S., Sonmez, N.K., Kaman, H., Uz, I., Uz, B.Y., Aslan, G.E.
Seasonal changes of spatial variation of some ground-water quality variables in a large irrigated coastal Mediterranean region of Turkey
(2016) *Sci. Total Environ*, 554, pp. 53-63.

- Omer, N.H.
Water Quality Parameters
(2019) *Water Quality-Science, Assessments and Policy, InTechOpen*, pp. 1-34.
K. Summers, Ed

- dan Saliran, J.P.
(2009) *Study on the River Water Quality Trends and Indexes in Peninsular Malaysia*, Water Resources Publicatio 21

- Tiwari, A., Hokajärvi, A.M., Domingo, J.S., Elk, M., Jayaprakash, B., Ryu, H., Siponen, S., Pitkänen, T.
Bacterial diversity and predicted enzymatic function in a multipurpose surface water system – from wastewater effluent discharges to drinking water production
(2021) *Environ. Microbiomes*, 16.

- Ramesh, C., Jain, S.
Which Physical, Chemical and Biological Parameters of Water Determine Its Quality?
(2017) *Solid Liquid Resource Management in Smart Cities View Project*,

- Curran, J.F., Zaggia, L., Quero, G.M.
Metagenomic characterization of microbial pollutants and antibiotic-and metal-resistance genes in sediments from the canals of Venice
(2022) *Water (Switzerland)*, 14.

- Hong, P.-Y., Mantilla-Calderon, D., Wang, C.
Metagenomics as a tool to monitor reclaimed-water quality
(2020) *Appl. Environ. Microbiol*, 86.

- van Rossum, T.V., Peabody, M.A., Uyaguari-Diaz, M.I., Cronin, K.I., Chan, M., Slobodan, J.R., Nesbitt, M.J., Brinkman, F.S.L.
Year-long metagenomic study of river microbiomes across land use and water quality
(2015) *Front. Microbiol*, 6.

- Brumfield, K.D., Hasan, N.A., Leddy, M.B., Cotruvo, J.A., Rashed, S.M., Colwell, R.R., Huq, A.
A comparative analysis of drinking water employing metagenomics
(2020) *PLoS One*, 15.

- Staley, C., Sadowsky, M.J.
Application of metagenomics to assess microbial communities in water and other environmental matrices
(2016) *J. Mar. Biol. Assoc. U. K*, 96, pp. 121-129.

- Hidayat, T., Samat, M.A.A., Elias, M.A. bin., Hadibarata, T.
Metagenomic analysis of 16S rRNA sequences from selected rivers in Johor

Malaysia
(2012) *J. Appl. Sci*, 12, pp. 354-361.

- Thomas, T., Gilbert, J., Meyer, F.
Metagenomics – a guide from sampling to data analysis
(2012) *Microb. Inf. Exp*, 2.

- Usharani, B.
Metagenomics study of the microbes in constructed wetland system treating sewage
(2019) *Int. Lett. Nat. Sci*, 74, pp. 26-48.

- Rizal, N.S.M., Neoh, H.M., Ramli, R., Periyasamy, P.R.A.L.K., Hanafiah, A., Samat, M.N.A., Tan, T.L., Khor, B.Y.
Advantages and limitations of 16S rRNA next-generation sequencing for pathogen identification in the diagnostic microbiology laboratory: perspectives from a middle-income country
(2020) *Diagnostics*, 10.

- Biessy, L., Pearman, J.K., Waters, S., Vandergoes, M.J., Wood, S.A.
Metagenomic insights to the functional potential of sediment microbial communities in freshwater lakes
(2022) *Metabarcoding Metagenomics*, 6, pp. 59-74.

- Bayat, A.
Science, medicine, and the future-bioinformatics
(2002) *BMJ-Br. Med. J*, 324, pp. 1018-1022.

- Lluch, J., Servant, F., Païssé, S., Valle, C., Valière, S., Kuchly, C., Vilchez, G., Lelouvier, B.
The characterization of novel tissue microbiota using an optimized 16S metagenomic sequencing pipeline
(2015) *PLoS One*, 10.

- Barlow, J.T., Bogatyrev, S.R., Ismagilov, R.F.
A quantitative sequencing framework for absolute abundance measurements of mucosal and lumenal microbial communities
(2020) *Nat. Commun*, 11.

- Alotaibi, M.O., Mohammed, A.E., Eltom, K.H.
Metagenomic analysis of bacterial communities of Wadi Namar Lake, Riyadh, Saudi Arabia
(2022) *Saudi J. Biol. Sci*, 29, pp. 3749-3758.

- Plotnikoff, R.W.
(2020) *Rarefaction of Benthic Macoinvertebrate Taxonomic Lists: Impact of Changes to the Taxon List and on B-IBI Scores*,
Snohomish County Public Works, Surface Water Management Division, Everett, WA

- Budka, A., Łacka, A., Szoszkiewicz, K.
The use of rarefaction and extrapolation as methods of estimating the effects of river eutrophication on macrophyte diversity
(2019) *Biodivers. Conserv*, 28, pp. 385-400.

- Xu, S., Yao, J., Ainiwaer, M., Hong, Y., Zhang, Y.
Analysis of bacterial community structure of activated sludge from wastewater treatment plants in winter
(2018) *BioMed Res. Int*, 2018.

- Neu, A.T., Allen, E.E., Roy, K.
Defining and Quantifying the Core Microbiome: Challenges and Prospects
(2021) *Proceedings of the National Academy of Sciences of the United States of America*,

- Shade, A., Handelsman, J.
Beyond the Venn diagram: the hunt for a core microbiome
(2012) *Environ. Microbiol*, 14, pp. 4-12.

- Tokatli, C., Kose, E., Cicek, A., Emiroglu, O., Bastatli, Y.
Use of cluster analysis to evaluate surface water quality: an application from downstream of Meric river basin (Edirne, Turkey)
(2015) *Int. J. Adv. Sci. Eng. Technol*, 3, pp. 33-35.

- Warsito, B., Sumiyati, S., Yasin, H., Faridah, H.
Evaluation of river water quality by using hierarchical clustering analysis
(2021) *IOP Conf. Ser.: Earth Environ. Sci*, 896.

- Abu-Khalaf, N., Khayat, S., Natsheh, B.
Multivariate data analysis to identify the groundwater pollution sources in Tulkarm area/Palestine
(2013) *Sci. Technol*, 3, pp. 99-104.

- das Kangabam, R., Silla, Y., Goswami, G., Barooah, M.
Bacterial operational taxonomic units replace the interactive roles of other operational taxonomic units under strong environmental changes
(2020) *Curr. Genomics*, 21, pp. 512-524.

- Ren, Z., Wang, F., Qu, X., Elser, J.J., Liu, Y., Chu, L.
Taxonomic and functional differences between microbial communities in Qinghai Lake and its input streams
(2017) *Front. Microbiol*, 8, p. 2319.

- Tao, X., Guo, F., Zhou, Q., Hu, F., Xiang, H., Xiao, G.G., Shang, D.
Bacterial community mapping of the intestinal tract in acute pancreatitis rats based on 16S rDNA gene sequence analysis
(2019) *RSC Adv*, 9, pp. 5025-5036.

- Willis, A.D.
Rarefaction, alpha diversity, and statistics
(2019) *Front. Microbiol*, 10.

- Thukral, A.K.
A review on measurement of Alpha diversity in biology
(2017) *Agric. Res. J*, 54, p. 1.

- Ju, F., Zhang, T.
16S rRNA gene high-throughput sequencing data mining of microbial diversity and interactions
(2015) *Appl. Microbiol. Biotechnol*, 99, pp. 4119-4129.

- Zlatković, S., Medić, O., Predojević, D., Nikolić, I., Subakov-Simić, G., Onjia, A., Berić, T., Stanković, S.
Spatio-temporal dynamics in physico-chemical properties, phytoplankton and bacterial diversity as an indication of the Bovan Reservoir water quality
(2022) *Water (Switzerland)*, 14.

- Anderson, I., Held, B., Lapidus, A., Nolan, M., Lucas, S., Tice, H., Kyrpides, N.C.
Genome sequence of the homoacetogenic bacterium Holophaga foetida type strain (TMBS4 T)
(2012) *Stand. Genomic Sci*, 6, pp. 174-184.

- Ma, J., Wu, S., Shekhar, N.V.R., Biswas, S., Sahu, A.K.
Determination of physicochemical parameters and levels of heavy metals in food

wastewater with environmental effects
(2020) *Bioinorg. Chem. Appl*, 2020, p. 8886093.

- Rajwa-Kuligiewicz, A., Bialik, R.J., Rowiński, P.M.
Dissolved oxygen and water temperature dynamics in lowland rivers over various timescales
(2015) *J. Hydrol. Hydromech*, 63, pp. 353-363.

- Kulkarni, S.J.
A review on research and studies on dissolved oxygen and its affecting parameters
(2016) *Int. J. Res. Rev*, 3, pp. 18-22.

- Girardi, R., Pinheiro, A., Torres, E., Kaufmann, V., Garbossa, L.H.P.
Evolution of the concentration of physical-chemical species in the watercourse after intense precipitation events obtained by high-frequency monitoring
(2016) *RBRH*, 21, pp. 653-665.

- Allafta, H., Opp, C.
Spatio-temporal variability and pollution sources identification of the surface sediments of Shatt Al-Arab River, Southern Iraq
(2020) *Sci. Rep*, 10.

- Yaakub, N., Raoff, M.N.A., Haris, M.N., Halim, A.A.A., Kamarudin, M.K.A.
Water quality index assessment around industrial area in Kuantan, Pahang
(2017) *J. Fundam. Appl. Sci*, 9, pp. 731-749.

- Al-Badaii, F., Shuhaimi-Othman, M., Gasim, M.B.
Water quality assessment of the Semenyih river, Selangor, Malaysia
(2013) *J. Chem*,

- Rahmanian, N., Ali, S.H.B., Homayoonfard, M., Ali, N.J., Rehan, M., Sadef, Y., Nizami, A.S.
Analysis of physiochemical parameters to evaluate the drinking water quality in the state of Perak, Malaysia
(2015) *J. Chem*, 2015.

- Geiger, J., Mesner, N.
(2000) *Utah Stream Team*,

- Yap, C.K., Chee, M.W., Shamarina, S., Edward, F.B., Chew, W., Tan, S.G.
(2011) *Assessment of surface water quality in the Malaysian Coastal Waters by using multivariate analyses (Penilaian Kualiti Air Permukaan di Perairan Pantai Malaysia Menggunakan Analisis Multivariat)*,
Sains Malaysiana

- McCauley, A., Jones, C., Jacobsen, J.
Soil pH and Organic Matter
(2009) *Nutrient Management Module*, 8, pp. 1-12.

- Ab Wahab, S.U.K., Shaibullah, S.H., Abu Samah, M.A., Mohd Aris, M.S.
An assessment of surface water quality and heavy metals involving the rare earth elements in Sungai Tunggak and Sungai Balok
(2016) *Int. J. Appl. Chem*, 12, pp. 146-151.

- Patil, P.N.
Physico-chemical parameters for testing of water-a review
(2012) *Int. J. Environ. Sci*, 3, pp. 1194-1207.

- Rosen, M.A., Bulucea, C.A., Mastorakis, N.E., Bulucea, C.A., Jeles, A.C., Brindusa, C.C.
Evaluating the thermal pollution caused by wastewaters discharged from a chain of

coal-fired power plants along a river
(2015) *Sustainability (Switzerland)*, 7, pp. 5920-5943.

- Miara, A., Vörösmarty, C.J., Macknick, J.E., Tidwell, V.C., Fekete, B., Corsi, F., Newmark, R.
Thermal pollution impacts on rivers and power supply in the Mississippi River watershed
(2018) *Environ. Res. Lett*, 13.

- Yang, P., Chua, L.H., Irvine, K.N., Nguyen, M.T., Low, E.
Impacts of a floating photovoltaic system on temperature and water quality in a shallow tropical reservoir
(2022) *Limnology*, 23, pp. 441-454.

- Davies-Colley, R.J., Smith, D.G.
Turbidity suspended sediment, and water clarity: a review
(2001) *JAWRA J. Am. Water Resour. Assoc*, 37, pp. 1085-1101.

- Mohammed, T.A.
Assessment of physico-chemical water quality of Bira Dam, Bati Wereda, Amhara Region, Ethiopia
(2014) *J. Aquacult. Res. Dev*, 5.
A

- Suratman, S., Sailan, M.I.M., Hee, Y.Y., Bedurus, E.A., Latif, M.T.
A preliminary study of water quality index in Terengganu River Basin, Malaysia (Kajian Awal Indeks Kualiti Air di Lembangan Sungai Terengganu, Malaysia)
(2015) *Sains Malaysiana*, 44.

- Marove, C.A., Sotozono, R., Tangviroon, P., Tabelin, C.B., Igarashi, T.
Assessment of soil, sediment and water contaminations around open-pit coal mines in Moatize, Tete province, Mozambique
(2022) *Environ. Adv/*, 8, p. 100215.

- Zia, H., Harris, N.R., Merrett, G.V., Rivers, M., Coles, N.
The impact of agricultural activities on water quality: a case for collaborative catchment-scale management using integrated wireless sensor networks
(2013) *Comput. Electron. Agric*, 96, pp. 126-138.

- Velmurugan, A., Swarnam, P., Subramani, T., Meena, B., Kaledhonkar, M.J.
Water Demand and Salinity
(2020) *Desalination-Challenges and Opportunities*,
M.H.D.A. Farahani, Vatanpour, A.H. Taheri, Eds., InTechOpen

- Williams, W.D.
Environmental threats to salt lakes and the likely status of inland saline ecosystems in 2025
(2002) *Environ. Conserv*, 29, pp. 154-167.

- Sukamari, I.A., Kwaji, B., Alheri, J., Abia, I.O.E.
(2020) *Application of Water Quality Index to Assess the Potability of Some Domestic Water Supply Sources in Mubi North*,
Nigeria

- Guignard, M.S., Leitch, A.R., Acquisti, C., Eizaguirre, C., Elser, J.J., Hessen, D.O., Jeyasingh, P.D., Leitch, I.J.
Impacts of nitrogen and phosphorus: from genomes to natural ecosystems and agriculture
(2017) *Front. Ecol. Evol*, 5.

- Doster, E., Zitomer, R., Chislock, M.F.
(2013) *Eutrophication: Causes, Consequences, and Controls in Aquatic Ecosystems, Effects of a Saccharomyces cerevisiae Fermentation Product on Liver Abscesses, Fecal Microbiome, and Resistome in Feedlot Cattle Raised Without Antibiotics View Project MEGARes: An Antimicrobial Resistance Database for High Throughput Sequencing View Project*,

- Wang, Q.S., Sun, D.B., Hao, W.P., Li, Y.Z., Mei, X.R., Zhang, Y.Q.
Human activities and nitrogen in waters
(2012) *Acta Ecol. Sin*, 32, pp. 174-179.

- Saat, A., Hamzah, Z.
Evaluation of heavy metal contamination levels of Balok river sediments in Pahang, Malaysia based on geoaccumulation index and supported with enrichment factor
(2015) *Malays. J. Anal. Sci*,

- Rezagama, A., Hibbaan, M., Arief Budihardjo, M.
Ammonia-nitrogen (NH₃ –N) and ammonium-nitrogen (NH₄₊ –N) equilibrium on the process of removing nitrogen by using tubular plastic media
(2017) *J. Mater. Environ. Sci*, 8, pp. 4915-4922.

- Zhou, L.
(2015) *Investigations of Ammonia Nitrogen in Aquaculture: The Methodology, Concentrations, Removal, and Pond Fertilization*,
A Dissertation Submitted to the Graduate Faculty of Auburn University

- Kumar, P., Lai, S.H., Wong, J.K., Mohd, N.S., Kamal, M.R., Afan, H.A., Ahmed, A.N., El-Shafie, A.
Review of nitrogen compounds prediction in water bodies using artificial neural networks and other models
(2020) *Sustainability (Switzerland)*, 12, p. 4359.

- Orarm, B.
(2014) *Water Research Center – Nitrate Nitrite Nitrogen in Surfacewater and Drinking Water*,
Water Research Center

- How, S.W., Lim, S.Y., Lim, P.B., Aris, A.M., Ngoh, G.C., Curtis, T.P., Chua, A.S.M.
Low-dissolved-oxygen nitrification in tropical sewage: an investigation on potential, performance and functional microbial community
(2018) *Water Sci. Technol*, 77, pp. 2274-2283.

- Mullins, G.L.
(2019) *Phosphorus, Agriculture & The Environment*,

- Singh, A.L., Tripathi, A.K., Kumar, A., Singh, V.K.
Nitrate and phosphate contamination in ground water of Varanasi, Uttar Pradesh, India
(2012) *J. Ind. Res. Technol*, 2, pp. 26-32.

- Bouamra, F., Drouiche, N., Ahmed, D.S., Lounici, H.
Treatment of water loaded with orthophosphate by electrocoagulation
(2012) *Procedia Eng*, 33, pp. 155-162.

- Domagalski, J.L., Johnson, H.
(2012) *Phosphorus and Groundwater: Establishing Links Between Agricultural Use and Transport to Streams*,
US Geological Survey Fact Sheet 3004

- Kent, R., Johnson, T.D., Rosen, M.R.
Status and trends of orthophosphate concentrations in groundwater used for public supply in California
(2020) *Environ. Monit. Assess*, 192.

- Tchounwou, P.B., Yedjou, C.G., Patlolla, A.K., Sutton, D.J.
Heavy metal toxicity and the environment
(2012) *Exp. Suppl*, 101, pp. 133-164.

- Ali, H., Khan, E., Ilahi, I.
Environmental chemistry and ecotoxicology of hazardous heavy metals: environmental persistence, toxicity, and bioaccumulation
(2019) *J. Chem*, 2019, p. 6730305.

- Masindi, V., Muedi, K.L.
(2018) *Environmental Contamination by Heavy Metals*,
H. El-Din M. Saleh, R.F. Aglan, Eds., Heavy Metals, InTechOpen

- Garrett, R.G.
Natural sources of metals to the environment
(2000) *Hum. Ecol. Risk Assess.: Int. J. (HERA)*, 6, pp. 945-963.

- Briffa, J., Sinagra, E., Blundell, R.
Heavy metal pollution in the environment and their toxicological effects on humans
(2020) *Heliyon*, 6.

- Huang, Z., Liu, C., Zhao, X., Dong, J., Zheng, B.
Risk assessment of heavy metals in the surface sediment at the drinking water source of the Xiangjiang River in South China
(2020) *Environ. Sci. Eur*, 32.

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